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# ON MILK PRODUCTION OF COWS ON FEEDS WITH DIFFERENT PROTEIN AND UREA LEVELS

ARTTURI I. VIRTANEN AND TERTTU ETTALA

LABORATORY OF THE FOUNDATION FOR CHEMICAL RESEARCH, BIOCHEMICAL RESEARCH INSTITUTE, HELSINKI, FINLAND

During the last seven years we have studied in this laboratory to what extent it is possible to produce milk on protein-free feed containing purified nutrients: starch, cellulose and sucrose. The results have shown that an annual milk yield of about 4000 kg can be achieved, when the nitrogen source consists of urea to which small amounts of ammonium sulphate and phosphate have been added.[1] As the many-sided laboratory investigations showed further that the composition of the milk produced on this feed corresponds to that of milk produced on normal feed in regard to protein, vitamins and flavour substances, new possibilities have opened for milk production. Proteins have thus lost their central position in the feed of dairy cows and new energy-providing nutrients can now be used in the feed.

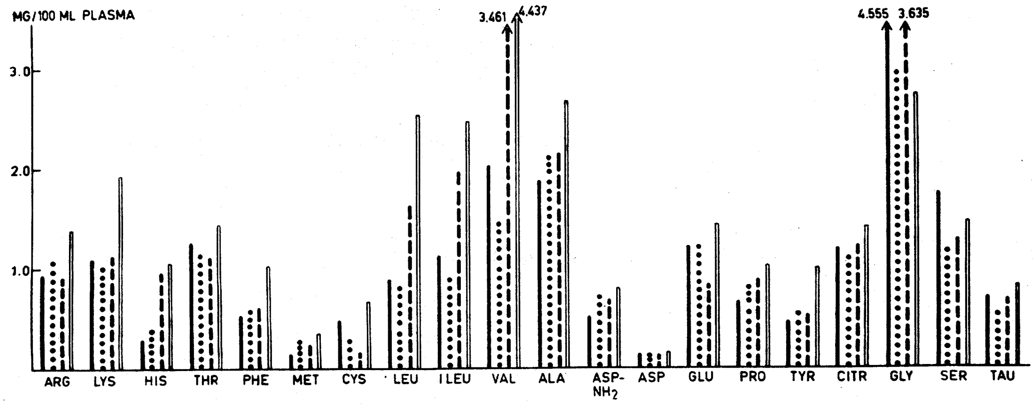
In countries rich in forests it is possible to produce a considerable amount of energy nutrition, suitable for the feed of dairy cattle, in connection with wood-processing industry. Hemicellulose, which forms for instance one third of the weight of birch wood, is easily hydrolyzed to sugars. Hydrolyzed hemicellulose, either as syrup or dry powder, is an easily digestible material, and becomes a valuable feed when supplemented with urea. During a period of three years we have performed feeding experiments using daily 3 kg dry hydrolyzed hemicellulose corresponding to 2.7 fu (= feed units). The protein content of the other fodders has been adjusted so that the amount of the digestible true protein with various cows has been about 20, 40 and 50 % of the digestible crude protein. The amounts of urea fed annually have correspondingly varied from about 180 kg to 90 kg.[2] The feed of the cows which have received the greatest amounts of urea has been made up of hemicellulose, potatoes and sugar beet pulp, the protein content of which is very low. In feed containing more true protein, it has been possible to include also oats and barley. In Table 1 the feed given and the milk yields are presented both as milk produced and as calculated standard milk (standard milk = 4.0 % fat, 3.2 % protein, 4.9 % sugar = 684 kcal/kg milk).

The evaluated milk yields of cows No:s 20 and 22 and the amounts of urea fed during the year 1968—69, which is still in progress, are also included in the table. As the amount of digestible true protein has varied, with different cows, from 20 to 50 % of the digestible crude protein, it is interesting that there are no greater differences in the milk production. It is true that the number of the test cows has been small, so that real comparisons cannot be made. As there are, however, in part very great differences in the contents of free essential amino acids of the blood plasma of the cows, one would expect that these differences would be reflected clearly in the milk yields (Fig. 1). Such is not the case, however. It seems that the mammary gland uses the amino acids of the plasma to a certain limit so effectively in protein synthesis that a much smaller amino acid concentration than normal is enough for even a high milk production. Amino acid analyses have not yet been performed on the blood arriving at and leaving the udder.

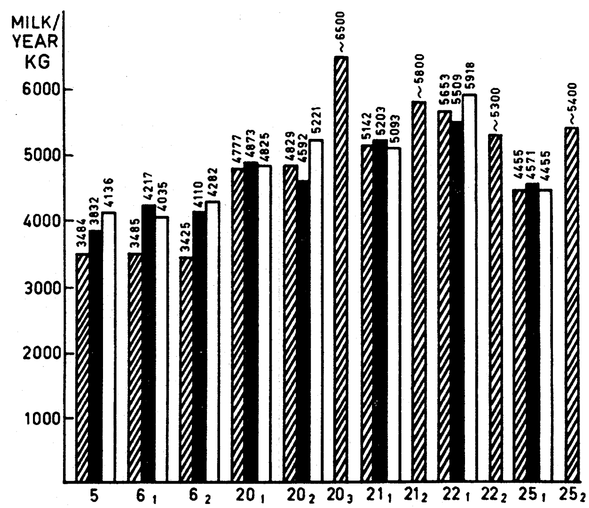
In Fig. 2 the milk yields of both test cows which have received protein-free purified feed (No:s. 5 & 6), and those of cows on the feed described in Table 1, are shown. The milk yields of cows which have received solely urea and ammonium nitrogen are surprisingly high but, however, clearly lower than those of cows which have received at least

Table 1. Annual feed consumption and milk production of cows on urea-rich, low-protein feed (= ULP-cows).

| Fed | Lila (No. 20) | | | | | Kelo (No. 21) | | | Lelo (No. 22) | | | Kairu (No. 25) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1966—67 | | 1967—68 | | 1968–69 | 1966—67 | | 1968–69 | 1967—68 | | 1968–69 | 1967—68 | | 1968–69 |
| | kg | fu | kg | fu | kg | kg | fu | kg | kg | fu | kg | kg | fu | kg |
| Potatoes, fresh | 6160 | 1176 | 5550 | 1077 | | — | — | | — | — | | — | — | — |
| Sugar beet pulp, dried | 1171 | 900 | 1642 | 1420 | | 1239 | 1071 | 1368 | 1440 | 1245 | | — | — | 551 |
| Oats | — | — | — | — | | 1402 | 1320 | 1350 | 1432 | 1348 | | 1348 | 1270 | 1856 |
| Barley | — | — | — | — | | 201 | 224 | 238 | 301 | 335 | | 731 | 815 | 393 |
| A.I.V. silage, fresh | — | — | — | — | | — | — | — | — | — | | 2905 | 415 | 57 |
| Hay | — | — | — | — | | — | — | — | — | — | | 688 | 379 | 689 |
| Barley straw | 561 | 175 | 432 | 121 | | 358 | 107 | 275 | 130 | 43 | | — | — | 394 |
| Hemicellulose powder | 847 | 770 | 996 | 907 | | 863 | 771 | 961 | 971 | 869 | | 1042 | 932 | 1027 |
| O-fiber | 578 | 193 | 352 | 286 | | 178 | 142 | 92 | 63 | 52 | | — | — | — |
| Vegetable oils | 34 | 55 | 9 | 15 | | — | — | — | — | — | | — | — | — |
| Urea | 136 | | 157 | | ~ 180 | 123 | | 142 | 129 | | ~ 142 | 89 | | 122 |
| Mineral mixture | 212 | | 203 | | | 140 | | 150 | 149 | | | 154 | | 121 |
| Vitamin A, mill. I.U. | 36.4 | | 51.7 | | | 36.2 | | 71.3 | 36.4 | | | 36.3 | | 71.6 |
| Vitamin $D_2+D_3$ mill.I.U | 7.3 | | 7.3 | | | 7.2 | | 7.3 | 7.3 | | | 7.3 | | 7.3 |
| Vitamin E, g | 202 | | 95.1 | | | 144.7 | | 17.2 | 142.7 | | | 36.4 | | 11.9 |
| Total | | 3269 | | 3826 | | | 3635 | | | 3892 | | | 3811 | |
| Dig.urea N, % of dig. crude prot. N | 64.5 | | 65.9 | | | 53.5 | | 57.0 | 53.2 | | | 35.5 | | 46.1 |
| Dig.true prot., % of dig. crude prot. | 21.1 | | 21.6 | | | 39.9 | | 36.9 | 40.3 | | | 50.5 | | 46.1 |
| Milk yield: | | | | | | | | | | | | | | |
| Milk produced | 4777 | | 4829 | | ~6500 | 5142 | | 5677 | 5653 | | ~5200 | 4455 | | 5522 |
| Stand.milk calc. on an energy basis | 4873 | | 4592 | | | 5203 | | 5847 | 5509 | | | 4571 | | 5133 |
| Stand. milk calc. on a protein basis | 4825 | | 5221 | | | 5093 | | 6188 | 5918 | | | 4455 | | 5884 |
| Annual yields: | | | | | | | | | | | | | | |
| Milk fat | 198 | 4.1 % | 177 | 3.7 % | | 208 | 4.1 % | 230 | 212 | 3.7 % | | 187 | 4.2 % | 190 |
| Milk protein | 155 | 3.24 „ | 167 | 3.46 „ | | 163 | 3.17 „ | 198 | 190 | 3.35 „ | | 142 | 3.20 „ | 190 |
| Milk sugar | 234 | 4.89 „ | 220 | 4.56 „ | | 258 | 5.03 „ | 283 | 277 | 4.90 „ | | 218 | 4,90 „ | 267 |
| Milk dry matter | 636 | 13.3 „ | 607 | 12.6 „ | | 674 | 13.1 „ | 761 | 730 | 12.9 „ | | 586 | 13,1 „ | 700 |




F i g. 1. The amounts of free amino acids in blood plasma. Protein-free feed (dark columns), dig true protein 20 % of dig. crude protein (dotted line columns), dig. true protein 40 % of dig. crude protein (broken line columns), normal protein-rich feed (white columns).




F i g. 2. Milk production of experimental cows on purified protein-free feed containing urea (cows No:s. 5 and 6) and on the urea-rich low-protein feed described in Table 1 (cows No:s. 20, 21, 22 and 25). The small numbers denote lactation periods on experimental feeding.

Striped columns = milk produced
Black columns = standard milk on energy basis
White columns = standard milk on protein basis.

some true protein. The lower milk production is due to the fact that the cows on a completely protein-free feed consume fewer feed units, at most 10—11 fu, whereas the cows which have received non-purified feed containing some protein consume 12—14 fu. As the purified nutrients are lacking in most various substances which are included in natural feed poor in protein, it is difficult to decide, what those factors are whose absence restricts the milk yield of cows fed purified nutrients. The deficiency of many other substances besides protein may be a limiting factor. Much research work is needed in order to elucidate this matter.

Our studies so far have opened the way for high milk production in many areas where the lack of feed rich in protein has greatly restricted production. In tropical areas, where the cultivation of grass does not succeed due to long periods of dryness and where in general plants rich in protein give poor yields, sugar cane molasses or raw sugar supplemented with urea is a suitable feed for dairy cattle. Starch-rich sweet potatoes and manioc and other plants of this type rich in starch are suitable to complete the fodder ration when sufficient amounts of urea are used to replace protein. Experiments of this kind have already been started in the tropics.

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REFERENCES

1. Virtanen, A. I., *Science* **153** (1966) 1603.
2. Virtanen, A. I., *Ann. Acad. Sci. Fennicae Ser. A II Chem.* (1968) No. 141.

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## Addition

Since the milk yield figures given in table 1 and figure 2 were not known exactly for all cows, when the report was sent for publication, the reprints have been furnished with a new table, dated 24/4/69, in which the final annual yields are given in full. The only exception is cow Lila, which is expected to milk for a further period of about 3 monts.

This supplementary data has been added to figure 2.

Table 1. Annual feed consumption and milk production of cows on urea-rich, low- protein feed (= ULP-cows)

| Fed | L i l a (No.20) | | | | | K e l o (No.21) | | | | L e l o (No.22) | | | | K a i r u (No.2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1966-67 | | 1967-68 | | 1968-69 | 1966-67 | | 1968-69 | | 1967-68 | | 1968-69 | | 1967-68 | | 1968 | |
| | kg | fu | kg | fu | kg | kg | fu | kg | fu | kg | fu | kg | fu | kg | fu | kg | |
| Potatoes, fresh | 6160 | 1176 | 5550 | 1077 | | – | – | – | – | – | – | – | – | – | – | – | |
| Sugar beet pulp,dried | 1171 | 900 | 1642 | 1420 | | 1239 | 1071 | 1368 | 1183 | 1440 | 1245 | 1544 | 1336 | – | – | 551 | |
| Oats | – | – | – | – | | 1402 | 1320 | 1350 | 1272 | 1432 | 1348 | 1426 | 1344 | 1348 | 1270 | 1856 | |
| Barley | – | – | – | – | | 201 | 224 | 238 | 265 | 301 | 335 | 89 | 100 | 731 | 815 | 393 | |
| A.I.V.silage, fresh | – | – | – | – | | – | – | – | – | – | – | – | – | 2905 | 415 | 57 | |
| Hay | – | – | – | – | | – | – | – | – | – | – | – | – | 688 | 379 | 689 | |
| Barley straw | 561 | 175 | 432 | 121 | | 358 | 107 | 275 | 82 | 130 | 43 | 242 | 68 | – | – | 394 | |
| Hemicellulose powder | 847 | 770 | 996 | 907 | | 863 | 771 | 961 | 861 | 971 | 869 | 939 | 841 | 1042 | 932 | 1027 | |
| O-fiber | 578 | 193 | 352 | 286 | | 178 | 142 | 92 | 74 | 63 | 52 | 129 | 103 | – | – | – | |
| Vegetable oils | 34 | 55 | 9 | 15 | | – | – | – | – | – | – | – | – | – | – | – | |
| Urea | 136 | | 157 | | ~165 | 123 | | 142 | | 129 | | 144 | | 89 | | 122 | |
| Mineral mixture | 212 | | 203 | | | 140 | | 150 | | 149 | | 154 | | 154 | | 121 | |
| Vitamin A,mill. I.U. | 36.4 | | 51.7 | | | 36.2 | | 71.3 | | 36.4 | | 71.6 | | 36.3 | | 71.6 | |
| Vitamin $D_2$+$D_3$ mill. I.U. | 7.3 | | 7.3 | | | 7.2 | | 7.3 | | 7.3 | | 7.3 | | 7.3 | | 7.3 | |
| Vitamin E, g | 202 | | 95,1 | | | 144,7 | | 17,2 | | 142,7 | | 17,5 | | 36,4 | | 11,9 | |
| Total | | 3269 | | 3826 | | | 3635 | | 3737 | | 3892 | | 3792 | | 3811 | | 4 |
| Dig. urea N, % of dig. crude prot.N | 64,5 | | 65,9 | | | 53,5 | | 57,0 | | 53,2 | | 57,0 | | 35,5 | | 46,1 | |
| Dig. true prot.,% of dig. crude prot. | 21,1 | | 21,6 | | | 39,9 | | 36,9 | | 40,3 | | 36,7 | | 50,5 | | 46,1 | |
| Milk yield: | | | | | | | | | | | | | | | | | |
| Milk produced | 4777 | | 4829 | | ~6500 | 5142 | | 5677 | | 5653 | | 5215 | | 4455 | | 5522 | |
| Stand. milk calc. on an energy basis | 4873 | | 4592 | | | 5203 | | 5847 | | 5509 | | 5768 | | 4571 | | 5133 | |
| Stand. milk calc. on a protein basis | 4825 | | 5221 | | | 5093 | | 6188 | | 5918 | | 5633 | | 4455 | | 5884 | |
| Annual yields: | | | | | | | | | | | | | | | | | |
| Milk fat | 198 | 4,1 % | 177 | 3,7 % | | 208 | 4,1 % | 230 | 4,1 % | 212 | 3,7 % | 247 | 4,7 % | 187 | 4,2 % | 190 | 3, |
| Milk protein | 155 | 3,24" | 167 | 3,46" | | 163 | 3,17" | 198 | 3,50" | 190 | 3,35" | 180 | 3,45" | 142 | 3,20" | 190 | 3, |
| Milk sugar | 234 | 4,89" | 220 | 4,56" | | 258 | 5,03" | 283 | 4,98" | 277 | 4,90" | 251 | 4,82" | 218 | 4,90" | 267 | 4, |
| Milk dry matter | 636 | 13,3" | 607 | 12,6" | | 674 | 13,1" | 761 | 13,4" | 730 | 12,9" | 720 | 13.8" | 586 | 13,1" | 700 | 1 |

Cow Oona, born 6/2 1966, heifer, adapted to test feeding 9/12 1967, calved 15/2 1968, cow calf 37 kg. Weight 29/2 1968 372 kg, 31/1 1969 425 kg.

Annual milk yield and feeding during the first lactation period, 15/2 1968 - 14/2 1969:

| Fed | kg | fu | Total N kg | Dig. urea-N kg |
|---|---|---|---|---|
| Starch | 1516 | 2424 | 0.3 | |
| Cellulose | 424 | | | |
| Sucrose | 658 | | | |
| Wheat straw | 95 | 22 | 0.7 | |
| Urea and ammonium salts | 171 | | 79.8 | 55.9 |
| Vegetable oils | 34 | 57 | | |
| Mineral mixture | 251 | | | |
| Polyethylene granules | 27 | | | |
| Vitamin A, million I.U. | 67.8 | | | |
| Vitamin $D_2$ + $D_3$, million I.U. | 7.1 | | | |
| Vitamin E | 14.14 g | | | |
| Total | | 2503 | 80.8 | 55.9 |
| Dig. urea-N % of dig. crude protein-N | | | | 98.8 |

Milk yield:

| | |
|---|---|
| Milk produced (0-milk) | 3494 kg |
| Stand. milk, calc. on an energy basis (684 Kcal/kg milk) | 3538 " |
| " " " " a protein " (3.2 % protein) | 3808 " |

Milk produced per year contained:

| | | |
|---|---|---|
| Dry matter | 461 kg | 13.2 % |
| Fat | 142 " | 4.1 " |
| Protein | 124 " | 3.50" |
| Sugar | 164 " | 4.64" |

## Test cows on purified nutrients without protein

Cow J a i r u, born 14/6 1961, adapted to test feeding 29/9 1963, calved first time 24/12 1963, cow calf 31 kg, second time 19/5 1965, cow calf 36 kg. Weight 21/5 1965 478 kg, 31/5 1966 480 kg.

Annual milk yield and feeding during the second lactation period 19/5 -65 - 18/5 -66.

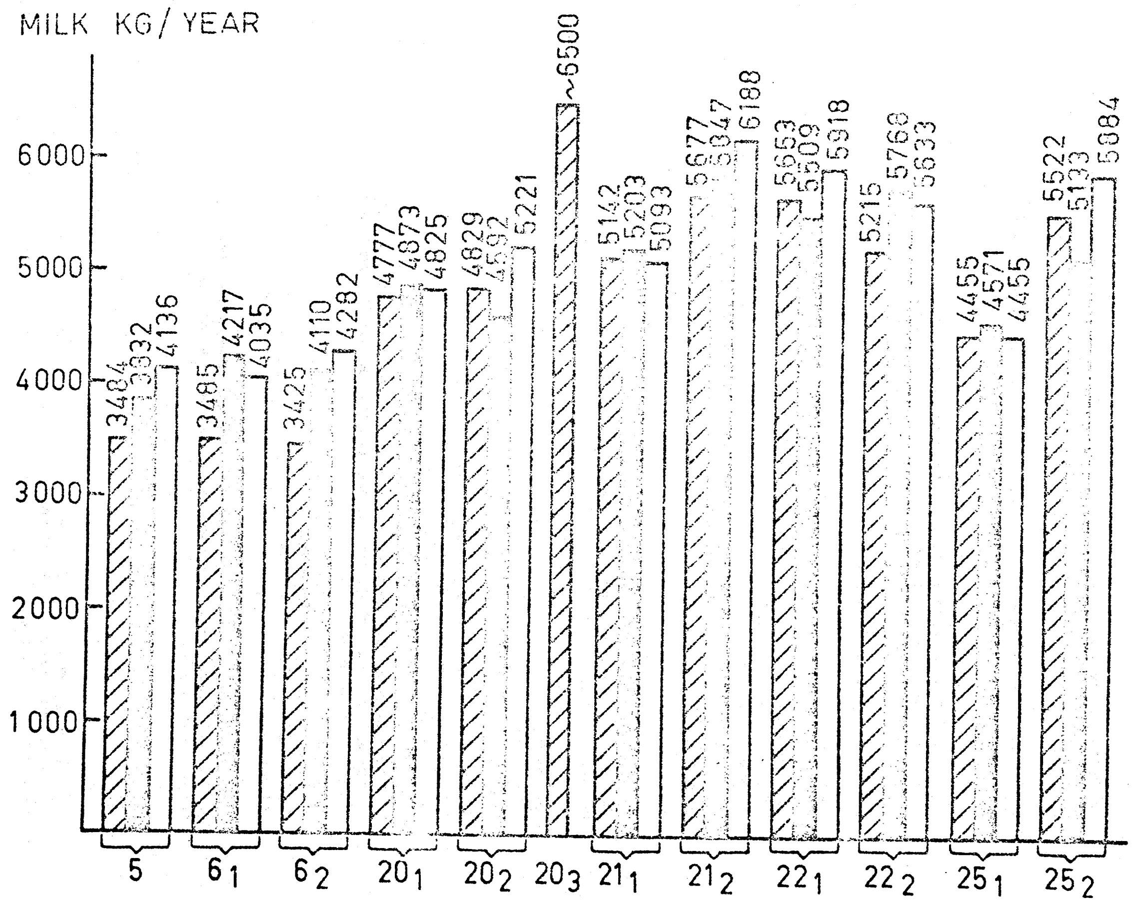
| Fed | kg | fu | Total N kg | Dig. urea-N kg |
|---|---|---|---|---|
| Starch | 1473 | 2632 | 0.3 | |
| Cellulose | 740 | | | |
| Sucrose | 672 | | | |
| Urea and ammonium salts | 169.7 | | 79.0 | 55.3 |
| Vegetable oils | 37.3 | 63 | | |
| Mineral mixture | 286 | | | |
| Vitamin A, million I.U. | 35.9 | | | |
| Vitamin $D_2 + D_3$, million I.U. | 7.2 | | | |
| Vitamin E | 138 g | | | |
| Total | | 2695 | 79.3 | 55.3 |
| Dig. urea-N % of dig. crude protein-N | | | | 99.6 |

Milk yield:

| | |
|---|---|
| Milk produced (0-milk) | 3484 kg |
| Stand. milk, calc. on an energy basis (684 Kcal/kg milk) | 3832 " |
| " " , " " a protein " (3.2 % protein) | 4136 " |

Milk produced per year contained:

| | | |
|---|---|---|
| Dry matter | 491 kg | 14.1 % |
| Fat | 159 " | 4.6 " |
| Protein | 132 " | 3.80" |
| Sugar | 164 " | 4.72" |


MILK KG/ YEAR
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4592
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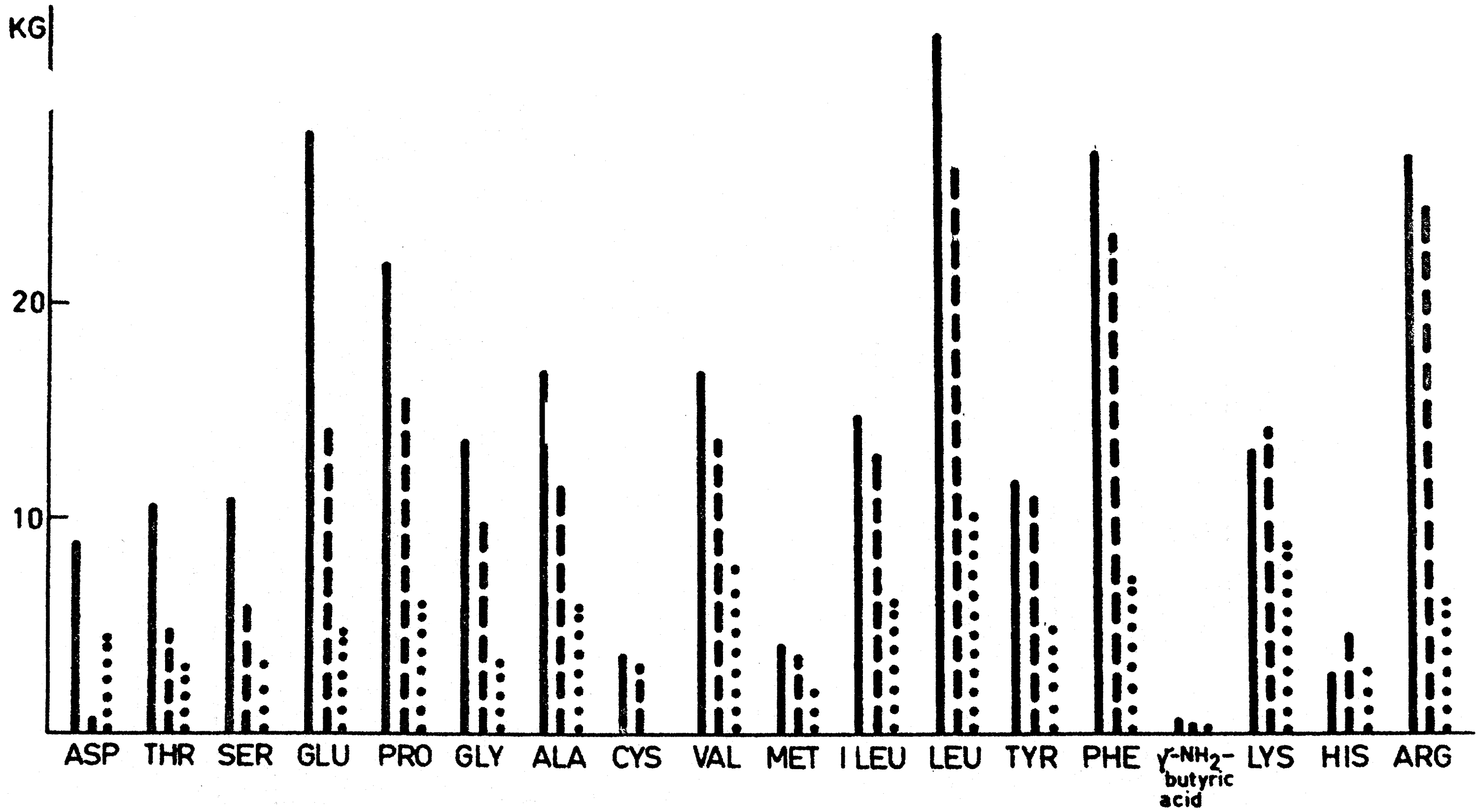
KG
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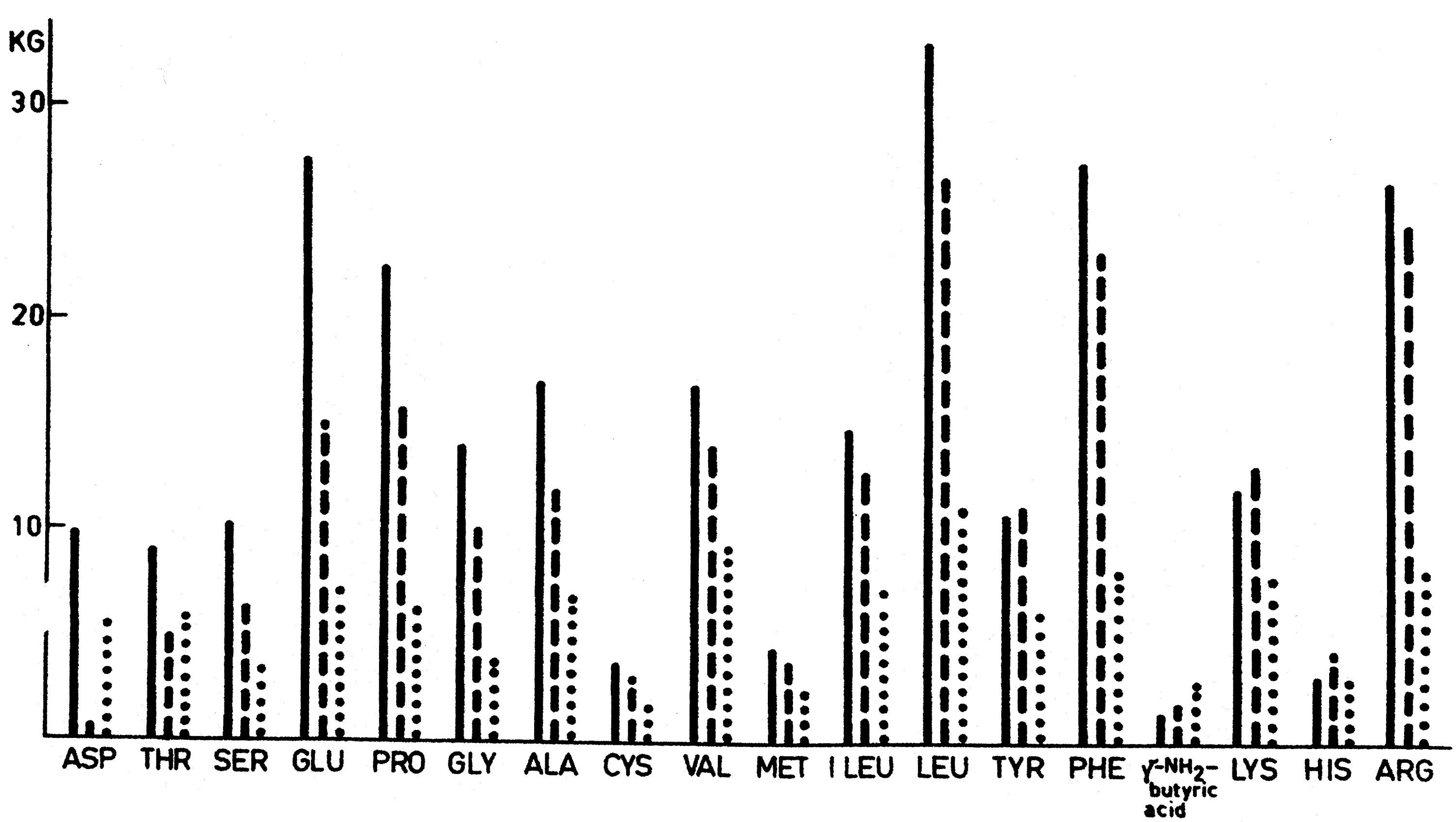
KG
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PHE
γ-NH2-butyric acid
LYS
HIS
ARG